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INSTITUTE SPECIAL REPORT

EVALUATION OF CENTERLINE-LIGHTING INDICATIONS FOR RUNWAY-DISTANCE REMAINING AND TAXIWAY EXITS

JUNE 1967

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Prepared for

FEDERAL AVIATION AGENCY

Systems Research & Development Service

THE INSTITUTE OF TRANSPORTATION AND TRAFFIC ENGINEERING
UNIVERSITY OF CALIFORNIA

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EVALUATION OF CENTERLINE-LIGHTING INDICATIONS FOR RUNWAY-DISTANCE REMAINING AND TAXIWAY EXITS

June 1967

Prepared by
D. M. Finch, R. Horonjeff and K. Mellander

This report has been prepared by the Institute of Transportation and Traffic Engineering, University of California for the Systems Research and Development Service, Federal Aviation Agency, under Contract No. FAA/ARDS-434. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policy of the FAA. This report does not constitute a standard, specification or regulation.

Institute of Transportation and Traffic Engineering
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ABSTRACT

Tests were conducted in the FAA Fog Chamber to determine the effectiveness of colored centerline lights for indicating runway-distance remaining and for marking high-speed taxiway exits (large-radius turnoffs) under daytime and nighttime visibility conditions down to 700 ft of visual range. The tests consisted of observations by pilots of various lighting patterns under simulated rollout conditions. The results of the tests indicate that red centerline lights can be effectively used for indicating runway-distance remaining, either in combination with white lights or alone if the intensity of the red lights is high enough to provide adequate guidance under reduced visibility. The test results also indicate that under conditions of 700-ft visual range, adequate identification and guidance for large-radius taxiway turnoffs can be provided by steady-burning, green lights along the taxiway centerlines, with a pattern having an equivalent intensity at least that of 1000-cp lights at 12.5-ft spacing in daytime and 500 cp at 12.5 ft at night. Steady-burning taxiway lights were preferred by the pilots over flashing lights by a very wide margin. Taxiway centerline lights having a much wider beam than that specified by the FAA were visible from a point on the runway centerline farther beyond the beginning of the taxiway turnoff than were the specified narrower-beam lights.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

For landing and takeoff operations under low visibility conditions, it is considered highly desirable to provide the pilot of an aircraft with as much orientation and guidance information as possible. One such kind of information, which has assumed increasing importance with the advent of high-speed jet aircraft, is the amount of runway distance remaining. Another essential type of information is that which will positively identify and delineate taxiway exits.

The question is how to present such information to the pilot most effectively. The basic choice is between an electronic or electromechanical system inside the cockpit, and visual indicators external to the aircraft. At present, the latter method seems more feasible and is the one with which this study is concerned.

Previous studies[1,2,*] have shown that under low-visibility conditions, pilots preferred to have the visual indicators for runway-distance remaining, or those providing identification and guidance for taxiway exits, located in the vicinity of the centerline. A possible solution, therefore, would be to provide the required information by the appropriate use of centerline lights.

Accordingly, in order to help determine the effectiveness of centerline-light systems for runway-distance information and for marking large-radius taxiway turnoffs, the FAA instituted an investigation to be carried out in the FAA Fog Chamber at the University of California. This investigation consisted of a series of daytime and nighttime tests in which pilot observers viewed a number of different runway and taxiway centerline-lighting configurations under simulated landing-rollout conditions. The test observations were made in several different visual ranges and the various test-light configurations were evaluated on the basis of the observers' responses to a questionnaire as well as volunteered comments.

This report describes the tests performed, presents and discusses the results, and sets forth some recommendations on the basis of these results.

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*References are listed at the end of the report.

METHODS AND PROCEDURES

Test Facilities and Equipment

Fog Chamber. The Fog Chamber, in which these tests were performed, is a long, narrow building whose height decreases along a $2\frac{1}{2}^{\circ}$ slope from one end to about the middle, and then stays constant for the remainder of its length. The roof and upper portion of the sides are covered with translucent corrugated panels to admit light for daytime fog studies. Light fixtures installed in the floor of this building are controlled to provide the various test lighting patterns as required. A cockpit cabin, suspended from a tramway carriage that runs on overhead rails down the length of the building, allows observers to view the lights while traveling along a simulated landing and rollout path. A detailed description of this test facility is given in a previously published report.[3]

All of the tests in the Fog Chamber reported herein were conducted at 1/5 scale. This means that all linear dimensions were reduced to 1/5 of their full-scale equivalents, while other parameters such as light intensity, fog density, and speed of travel were reduced by appropriate scale factors so that the visual scene in the Fog Chamber would appear the same to the observer as does the full-scale equivalent. With a linear scale factor of 1/5, the observer's eye height above the Fog Chamber runway during a test run was equivalent to a full scale value of 22 ft. All dimensions given in this report in connection with the Fog Chamber tests are corresponding full-scale values.

Fog is generated inside the building by a compressed-air and water system which forces a fine spray out of nozzles located at various points along the walls. This system can be controlled to maintain a fog of the required density throughout the tests. In the tests described here, fog density was maintained at the required level by means of a number of short-baseline transmissometers located in various parts of the test area.

Test Lights. Two types of centerline light fixtures, here designated A and B, were used in these tests. The type A fixture (Fig. 1) consisted of a bidirectional lamp-housing assembly manufactured by the Structural Electric Products Corp. (P/N 18469), and a 45-watt quartz-iodine lamp (type Q6.6A/T2½/1CL). Special light-shields were attached to the lamp housing to help shape the beam. The type A fixture was used at equivalent full-scale light intensities of 5000 cp and 1000 cp, with corresponding photometric distributions as shown in Figs. 2 and 3.

The type B fixture (Fig. 4) consisted of a Sylvania pancake fixture using a 45-watt quartz-iodine lamp raised about 1/16 in. from its normal position so that the lower part of the light beam would clear the upper edge of the fixture. As indicated in Fig. 5, the type B fixture, with a maximum intensity of 1000 cp (full scale), provided a considerably broader light beam than did the type A.

The centerline-light fixtures were equipped with color filters as required by the tests. These filters were Standard Aviation Red or Green with light transmission values of approximately 7% and 18% respectively.*

Test Procedures

The tests were divided into two parts, each consisting of daytime and nighttime visual observations of the test-light patterns by pilots riding in the cockpit of the Fog Chamber's tramway system. The tests of part I dealt with runway-distance remaining information while those of part II concerned taxiway exit indications. The names and affiliations of the pilot observers are given in Appendix C. Other details of the tests are set forth in the following paragraphs.

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*The filters were supplied by Charles Douglas of the National Bureau of Standards.

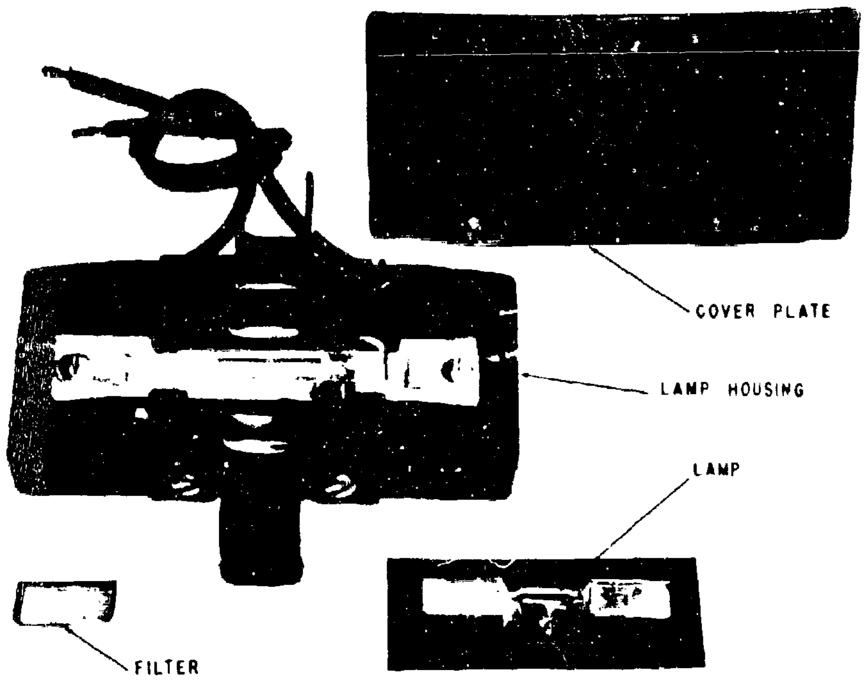


Fig. 1 - Type A light fixture.

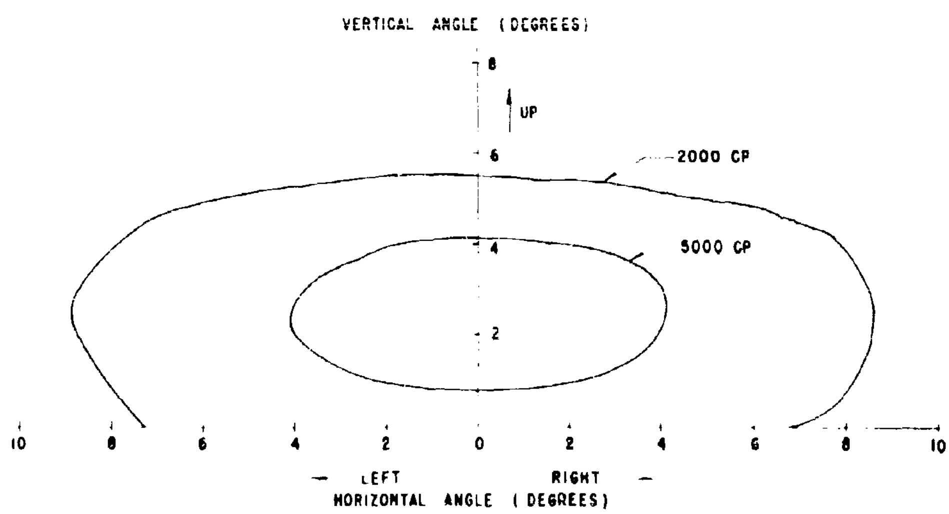


Fig. 2 - Isocandela chart for type A fixture operated at 5000-cp maximum intensity.

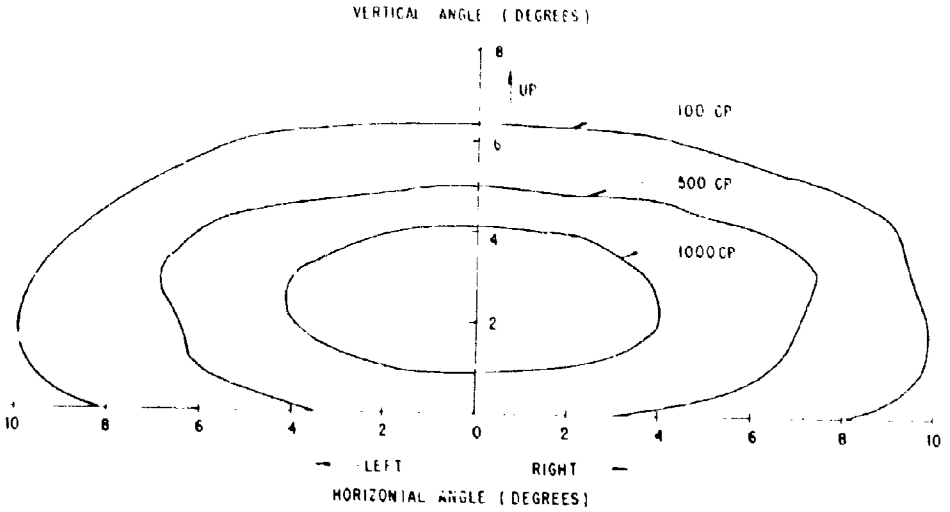


Fig. 3 - Isocandela chart for type A fixture operated at 1000-cp maximum intensity.

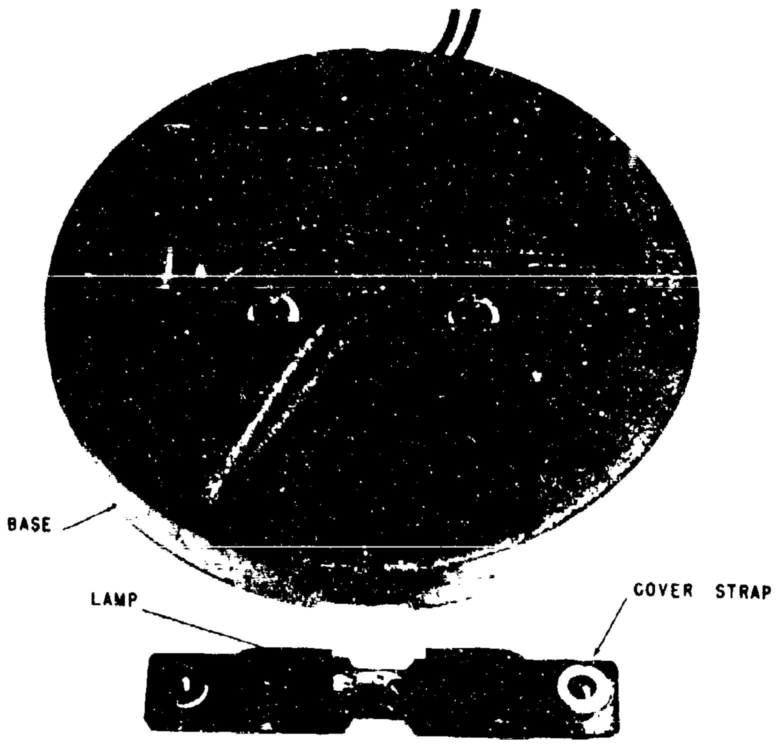


Fig. 4 - Type B light fixture.

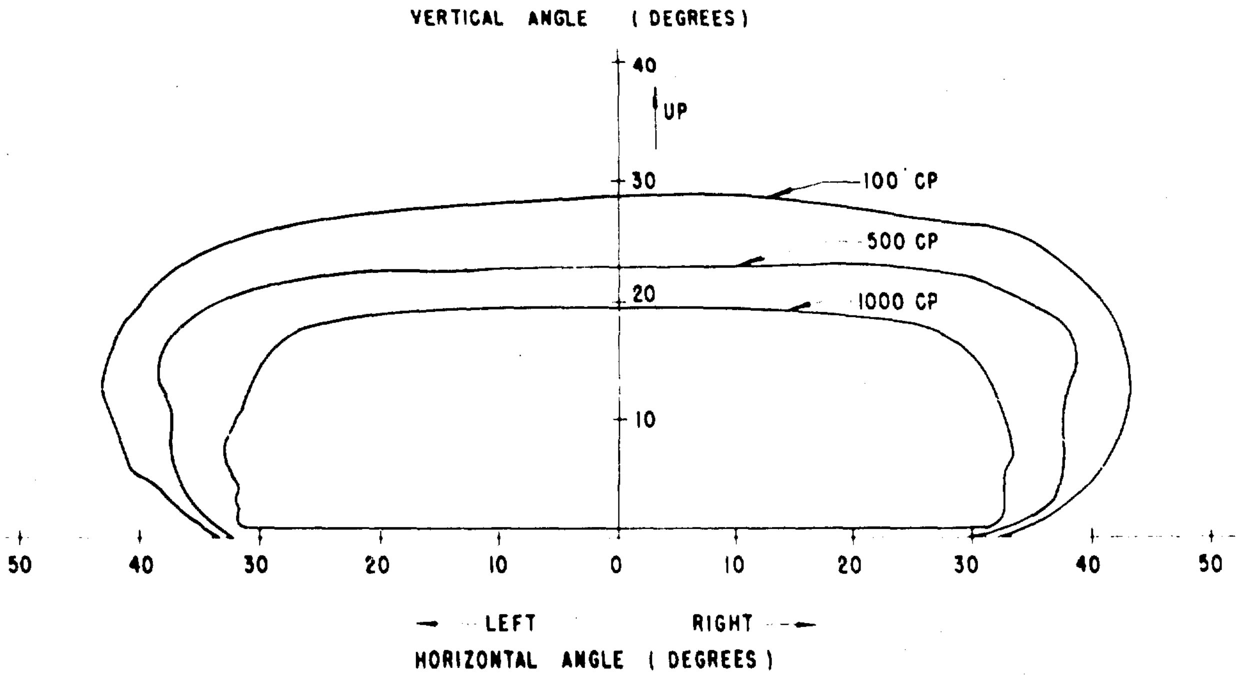


Fig. 5 - Isocandela chart for type B fixture.

Part I - Runway Distance-Remaining Tests. In this part of the investigation, the runway centerline lighting consisted of a 1000-ft section of white lights, followed by a section of alternate red and white lights for the next-to-last 1000 ft of the runway and a section of all red lights for the last 1000 ft as shown in Fig. 6. The light fixture used in these tests was the type A, previously described, with a maximum light intensity of 5000 cp (in white light) and a spacing between fixtures of 50 ft. The runway centerline lights were the only ones turned on in the test area during these tests.

Test observations of the above lighting pattern were made in both daytime and nighttime fog conditions of 1200-ft and 700-ft visual range. All of the daytime tests were performed under conditions of bright sunlight outside the Fog Chamber, resulting in a background luminance of 400 to 500 footlamberts inside the chamber.

Test runs were made by a total of 22 pilots in the daytime and 8 pilots at night. As indicated in Fig. 6, each test run started at a point about 1000 ft before the beginning of the red/white centerline-light section with the tramway cockpit, in which the observers rode, reaching a speed of roughly 60-70 mph (full scale) over the test-lighting pattern and then beginning to decelerate about 400 ft from the end of the runway. At the completion of each test run, the observers who took part answered several questions on a questionnaire form (see Appendix A) and added written comments if they so desired.

Part II - Taxiway Exit Tests. In this part of the investigation, the effectiveness of green taxiway centerline lights for marking large-radius taxiway turnoffs was evaluated in a manner similar to that of part I. Two taxiway turnoffs were set up in the Fog Chamber test area by installing lights as indicated in Fig. 7. Both turnoffs were geometrically the same, but one was made up of the relatively narrow-beam type A fixture, while the other consisted of the wider-beam type B fixture. Only one or the other of these turnoffs was turned on for any given test. The taxiway light fixtures were spaced 12.5 ft apart with alternate lights turned off to provide a 25-ft spacing when necessary in the tests. Both sets of lights were operated in either the steady-burning or flashing mode during the tests. In the steady-burning mode, the lights were operated at a maximum intensity of 500 cp or 1000 cp as required. In the flashing mode, the

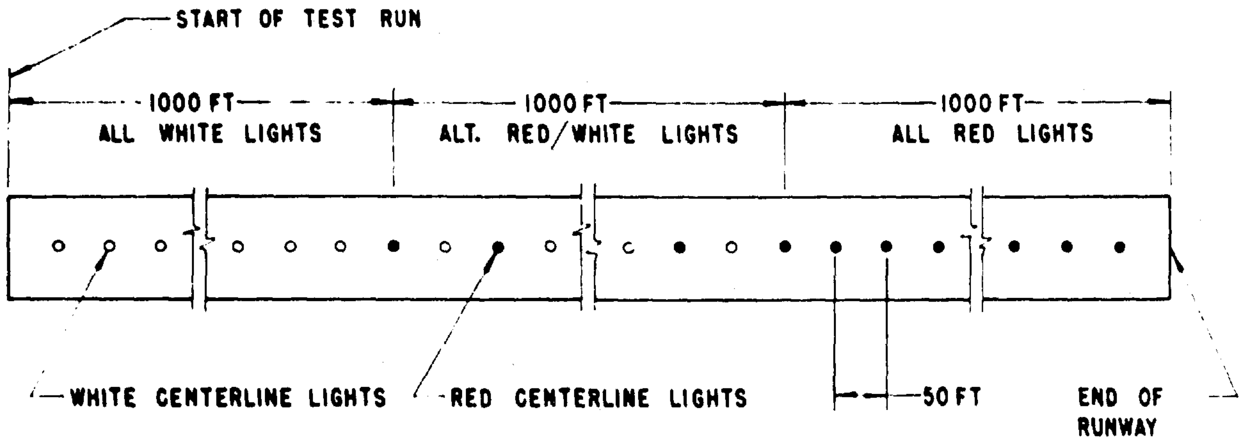
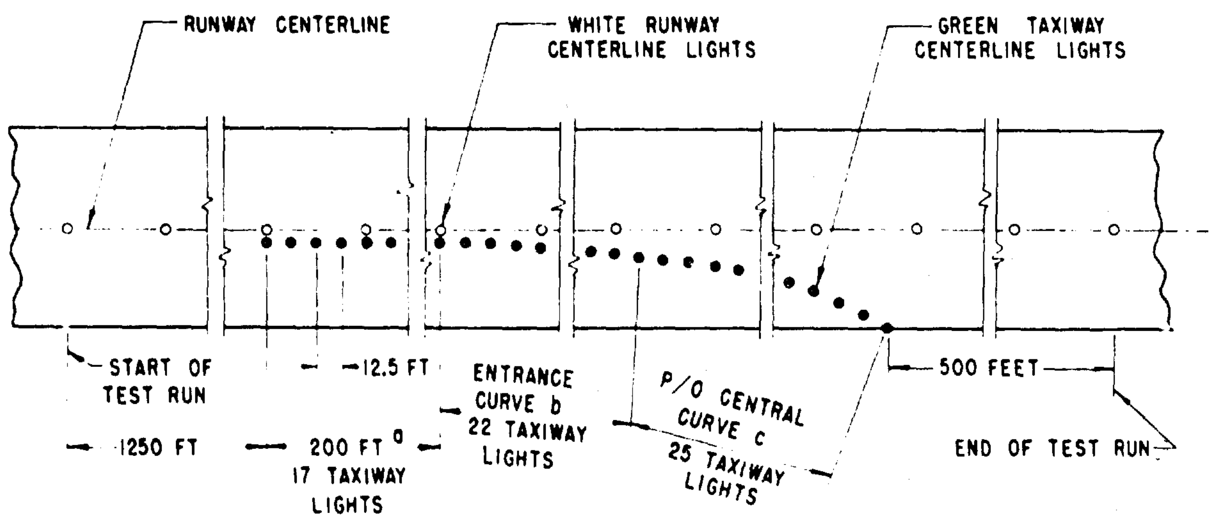


Fig. 6 - Layout of runway centerline lights for distance-remaining tests.



NOTES

a. STRAIGHT TAXIWAY - LIGHT SECTION PARALLEL TO RUNWAY CENTERLINE

b. RADIUS OF CURVATURE - 3206.5 FEET

c. RADIUS OF CURVATURE - 1826.8 FEET

Fig. 7 - Layout of centerline lights for taxiway-exit tests.

lighting circuits were set for a flash rate of about 1 per second with approximately equal on/off periods. Although the lights were set for a maximum intensity of 1000 cp, the peak intensity obtained during a flash was only 700 cp because of the thermal inertia of the lamps. All fixtures used as taxiway lights were masked to make them unidirectional. The lighting in all of the taxiway tests included white runway centerline lights at 5000 cp maximum intensity and 50 ft spacing; no edge lights were used.

Test observations of the taxiway centerline lighting configurations were made under conditions of clear weather and visual ranges of 1200 ft and 700 ft in both day and nighttime. The background luminance in the Fog Chamber during the daytime tests was approximately 400-500 fL.

A total of 24 pilots participated as observers in the daytime tests with the number making runs for each combination of visual range and lighting conditions varying somewhat as indicated in the results. In the nighttime tests, observation runs were made by a total of 8 pilots for each set of test conditions. As indicated in Fig. 7, each test run started at a point about 1250 ft before the first of the taxiway lights and ended about 500 ft beyond the last of the taxiway lights. The simulated speed of travel was about 50 mph in the clear-weather runs and about 15 mph under the fog conditions. At the end of a given test run, the observers who took part answered the appropriate question on the questionnaire form provided for the purpose (see Appendix A).

The sequence of both daytime and nighttime test observations was as follows:

1. Under clear weather conditions, all of the pilots, two at a time, observed the narrow-beam taxiway-lights operated in the steady-burning mode with the lights set at 500 cp maximum intensity and 25-ft spacing.

2. Those pilots who indicated on their questionnaire form that the above taxiway lighting configuration was not adequate for identification and guidance under the given conditions then observed the same taxiway lights with the spacing reduced to 12.5 ft.

3. Any of the pilots who observed the lighting configuration of 2 above and found it not adequate next made test runs with the taxiway lights set at 1000 cp maximum intensity and 25-ft spacing.

4. Any of the pilots who still considered the taxiway lighting inadequate observed the 1000-cp lights with the 12.5-ft spacing.

5. All of the pilots then observed the narrow-beam taxiway lights operated in the flashing mode with the lights spaced 25 ft apart.

6. The test-run sequence of 1 through 5 above was repeated for the wide-beam taxiway lights.

7. When all of the clear-weather observations had been completed, the visibility in the Fog Chamber was set at 1200-ft visual range and the test sequence of 1 through 6 above was repeated.

8. Finally, the visibility in the Fog Chamber was reduced to 700-ft visual range and the entire test sequence again repeated.

TEST RESULTS AND DISCUSSION

Part I — Runway-Distance Remaining Tests

In answer to the first two questions asked concerning the runway-distance remaining observations, the pilots taking part responded as follows:

1. Could you distinguish between the red centerline and the alternate red-white centerline?

	Daytime Yes	Daytime No	Nighttime Yes	Nighttime No
1200 ft visual range	21	1	8	0
700 ft visual range	21	1	8	0

2. Does a colored centerline give you useful information on distance to go?

	Daytime Yes	Daytime No	Nighttime Yes	Nighttime No
1200 ft visual range	22	0	8	0
700 ft visual range	22	0	8	0

It should be pointed out that in these tests no real effort was made to provide actual distance information, but to determine principally if colored centerline lights can be effective in calling a pilot's attention to transitions from one section to another along the runway. Clearly, if this is the case, then one or more suitable configurations of such lights could be used to indicate to the pilot approximately how much of the runway remained.

The results tabulated above seem to indicate unmistakably that the colored centerline-light configurations were effective down to the 700-ft visual range. Although question 1 dealt only with the transition from the section of alternate red-white lights to that of all-red lights, the gist of the pilots' comments with regard to these tests indicates that the transition from the all-white lights to the alternate red-white was also effective but perhaps to a lesser degree. (The pilots' comments are given verbatim in Appendix B.)

Those pilots who answered yes to question 2 were also asked if they preferred the solid red or the alternate red-white configuration for the entire distance. The responses were as follows:

	Day	Night
Prefer solid red	8	1
Prefer alternate red-white	8	2
No preference	2	3

Although the intent of this question was to determine if one or the other of the above patterns was the more effective, a substantial number of pilots indicated by their comments that they preferred some combination of the two with each pattern denoting a different zone as the end of the runway is approached. However, these observers' opinions with respect to the sequence of the patterns and the distance that should be covered by each varied considerably.

In general, the pilots indicated by their comments that although the solid-red configuration provided a more marked transition than did the alternate red-white, the former was not visible over a great enough distance in the 700-ft visual range to provide adequate guidance, particularly in the daytime. This reaction on the part of the pilots is not surprising when it is recalled that the red-light filters used in these tests have a transmission value of only 7% and thus drastically cut the effective intensity of the lights.

Part II — Taxiway Tests

The results of the taxiway tests are shown in the bar charts of Figs. 8 and 9. Fig. 8 covers the observations made with the lights operated in the steady-burning mode, the bars denoting the adequacy of the various taxiway lighting configurations for identification and guidance under each of the different visibility conditions as indicated by the pilots' responses on the questionnaire.

From these charts it can be seen that as the visual range was decreased, the equivalent intensity (defined as the combination of maximum candlepower and spacing) of the lighting pattern had to increase to be considered adequate. Thus, for example, under the daytime clear-weather conditions, approximately 90% of the observers found the narrow-beam pattern with the lights at 500 cp and 25 ft spacing adequate, whereas in the 700-ft visual range, only 10% said this same configuration was adequate. The same general effect holds true for the wide-beam pattern and for the nighttime conditions as well. As expected, also, a somewhat greater equivalent intensity of the taxiway lighting pattern was required by the pilots in the daytime than at night for any given visual range.

Fig. 8 shows that in 1200 ft of visual range during the day, 95% of the pilots would consider the narrow-beam taxiway lighting configuration with 1000-cp lights at 25-ft spacing adequate. For the wide-beam lights, 90% of the pilots would consider the configuration with 500 cp at 12.5 ft spacing adequate. It can also be seen that under the same visual-range condition at night, the 500-cp lighting configurations, with either narrow-beam or wide-beam lights, were found adequate by all of the observers who took part.

Under daytime conditions of 700-ft visual range, the lighting configuration considered adequate by the largest percentage of the observers, in the case of both the narrow-beam and the wide-beam pattern, was the one with the lights at 1000 cp and 12.5-ft spacing. This was the configuration with the highest equivalent intensity of those tested. In addition, some observers indicated that even this configuration was not adequate under the given visibility conditions. This response was given by 20% of the observers for the narrow-beam lights and 10% for the wide-beam lights. At night, in the 700-ft visual range, the 500-cp lighting configurations at the 25-ft and 12.5-ft spacings were found adequate by almost all of the participating observers. Only 1 of the 8 pilots viewing the wide-beam patterns indicated that he would require 1000-cp lights at 25-ft spacing for adequate guidance.

Although it is difficult to ascertain from either the questionnaire responses or the pilots' comments whether a consensus exists with regard to preference for the narrow-beam or the wide-beam lights, it can be seen that the wide-beam lights may provide a certain advantage as illustrated by the series of photographs shown in Fig. 10. These photographs show that the wide-beam taxiway lights are clearly visible from a point near the runway centerline considerably farther beyond the beginning of the taxiway turnoff than in the case of the narrow-beam lights. It seems reasonable to assume, therefore, that the wide-beam lights would enable a pilot who has rolled his aircraft past the designated taxiway exit to pick up the taxiway lights from a point farther beyond the beginning of the turnoff, and thus allow him a greater operational margin.

The results of the test observations made with the taxiway lights operated in the flashing mode are shown in Fig. 9. In these tests, the observers were asked to indicate whether or not they believed the flashing lights provided better identification and guidance than did the steady-burning lights for the corresponding patterns. As shown by the bar charts in Fig. 9, the observers responded overwhelmingly that the flashing lights were not better under any of the visibility conditions studied. These reactions, moreover, are further supported by the pilots' comments as given in Appendix B. It should be borne in mind, of course, that in the flashing mode the lights reached a peak intensity of only 700 cp as compared to 1000 cp in the steady-burning mode. Nevertheless, it seems clear from their comments that the pilots objected more to the flash characteristic of the lights than to the lower intensity.

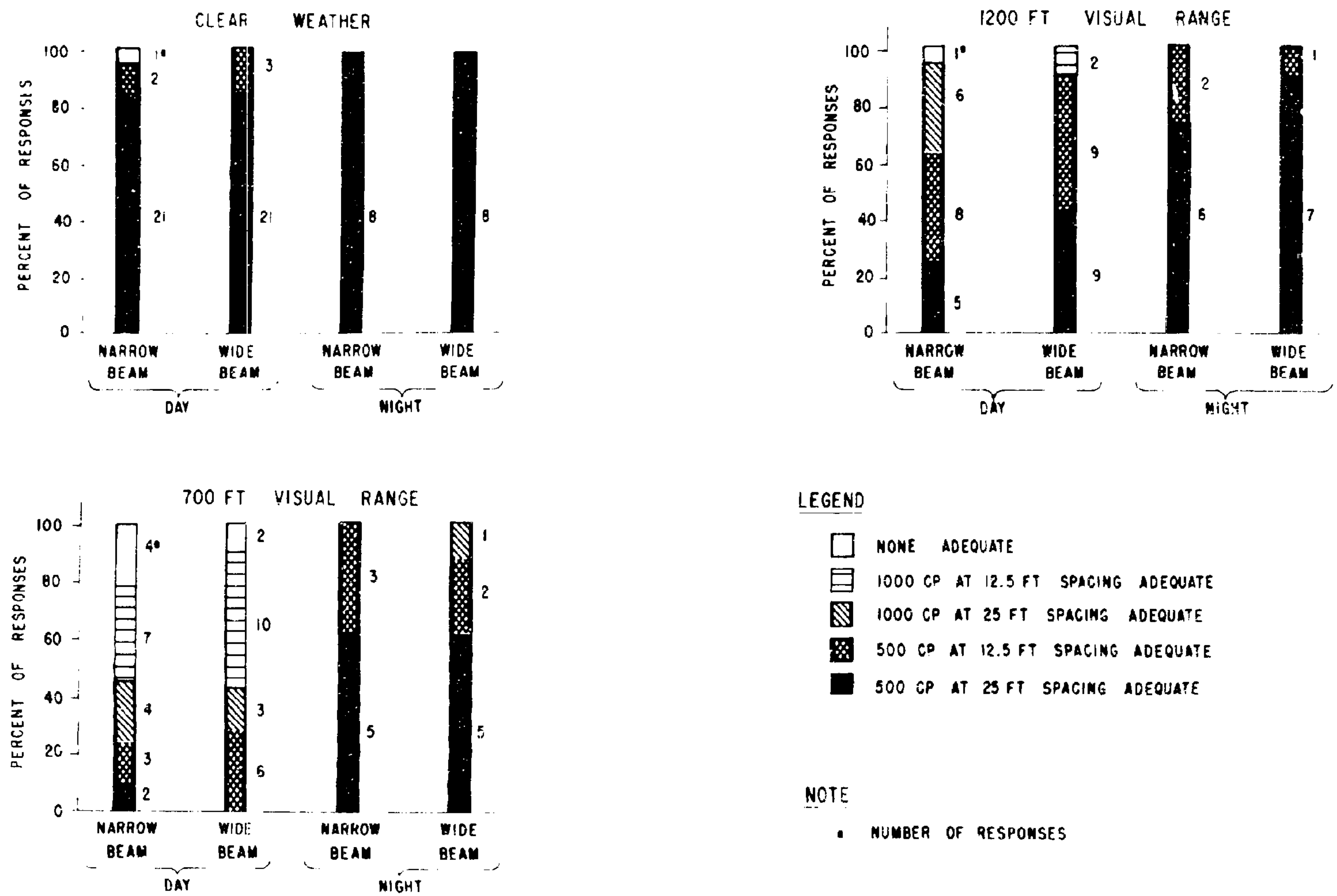


Fig. 8 - Percentage and number of pilot observers indicating preference for the various configurations of taxiway centerline lights in steady-burning mode.

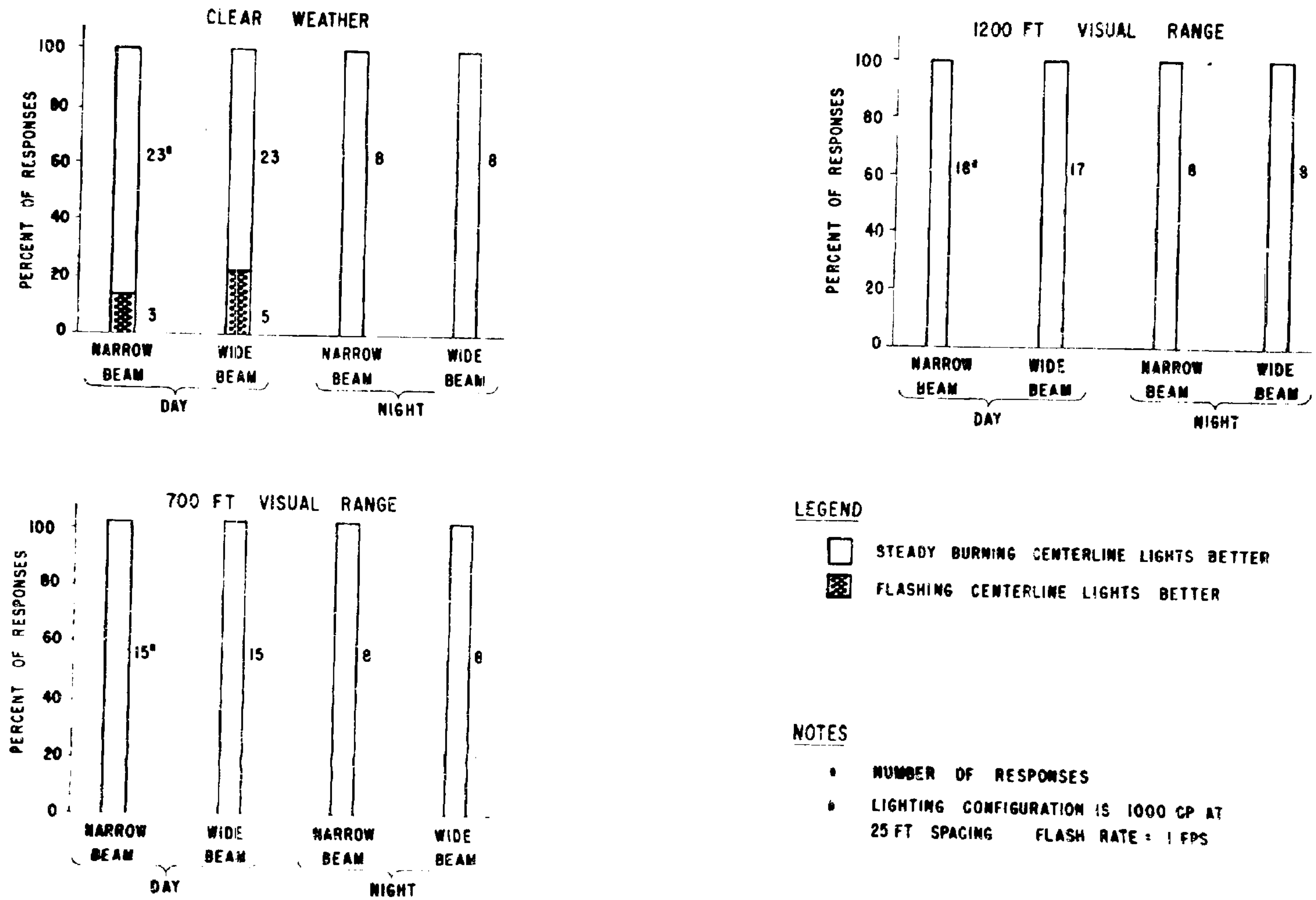
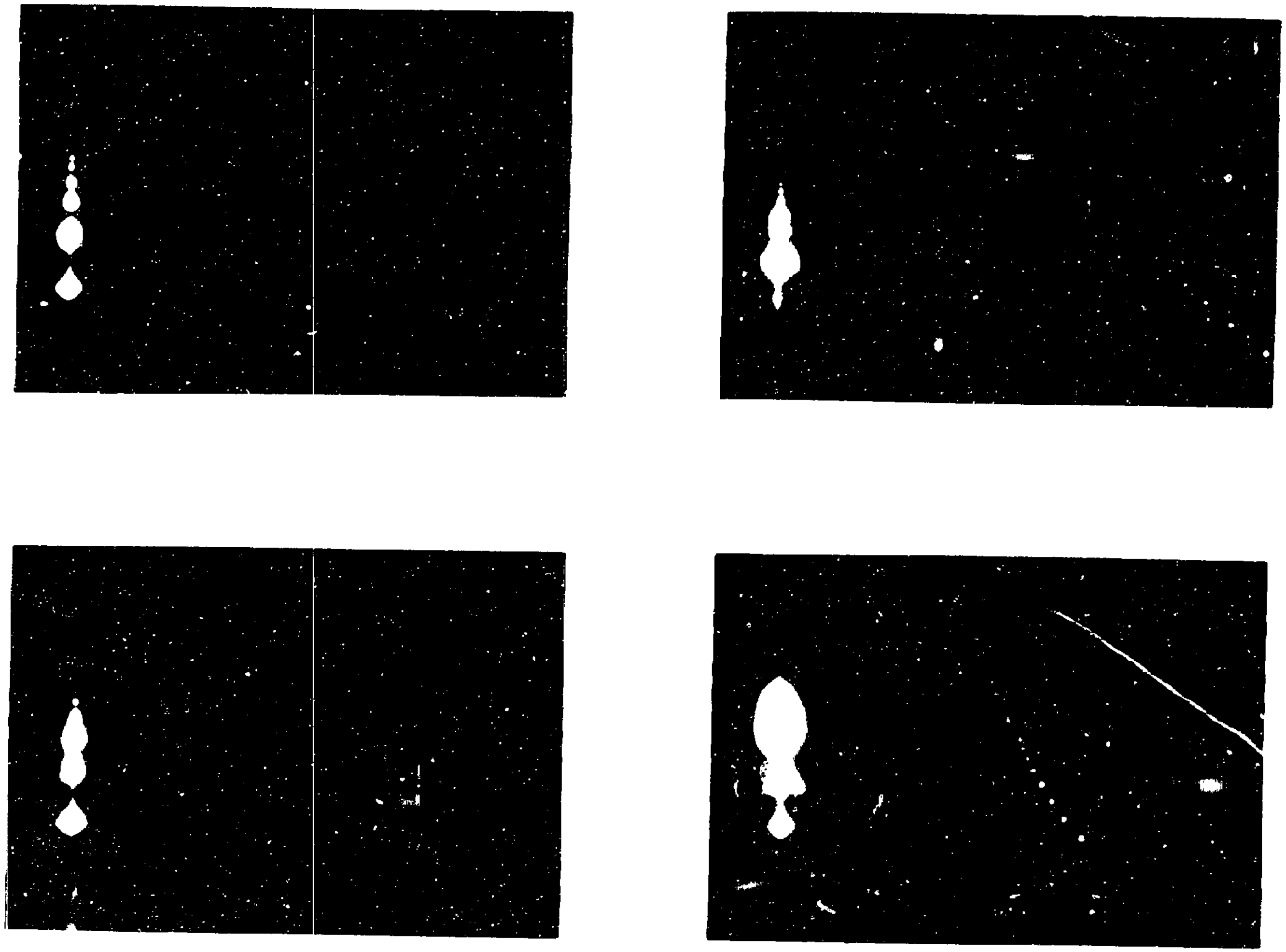


Fig. 9 - Percentage and number of pilot observers indicating preference for flashing or steady-burning taxiway centerline lights.

NARROW-BEAM TAXIWAY LIGHTS

WIDE-BEAM TAXIWAY LIGHTS



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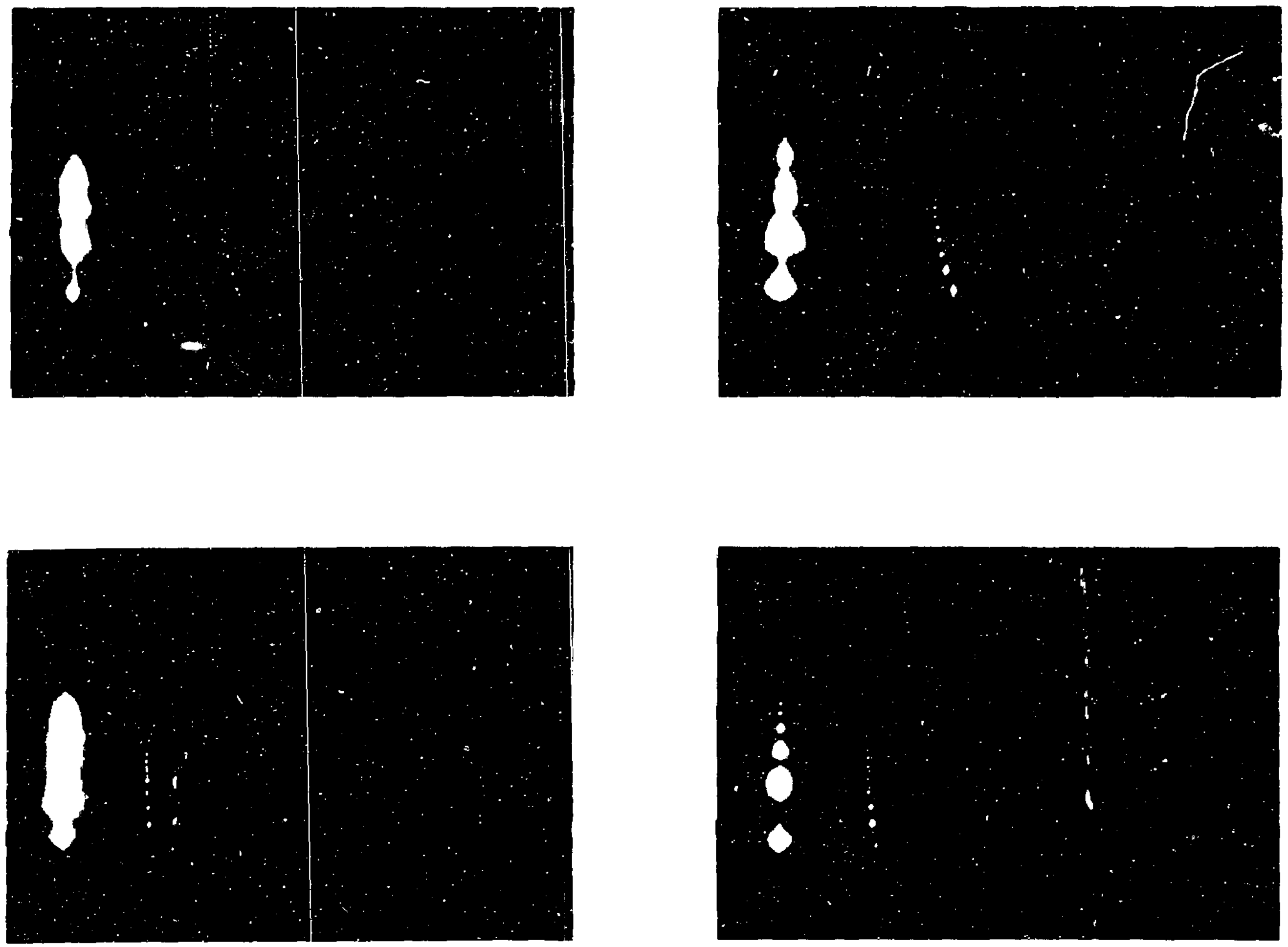

400 FT

300 FT

Fig. 10 - Fog Chamber photographs comparing visibilities of narrow-beam and wide-beam taxiway centerline lights in nighttime condition of 700-ft visual range. The photographs were taken from points on the runway centerline at various distances beyond the beginning of the taxiway turnoff as indicated by the figures at right.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions are based entirely on the tests conducted in the Fog Chamber as herein described.

1. Red centerline lights can be effectively used for runway-distance remaining information under low-visibility conditions down to 700 ft of visual range.

2. The transition between one longitudinal section of runway and the next is indicated more effectively by a pattern of all-red lights than by one with alternate red and white lights. Under low-visibility conditions, however, the guidance provided by a pattern of all-red lights is poorer than that provided by a pattern incorporating white lights in addition to the red.

3. In a centerline lighting system designed to provide runway-distance remaining information, it is probably desirable to employ a combination of patterns using red and white lights rather than just a single pattern.

4. Under clear-weather conditions, both daytime and nighttime, adequate identification and guidance for large-radius taxiway turnoffs is provided by steady-burning, green taxiway-centerline lights at 500-cp maximum intensity and 25-ft spacing.

5. In 1200-ft of visual range, during daytime, adequate identification and guidance for large-radius taxiway turnoffs is provided by a lighting configuration of 1000-cp narrow-beam lights at 25-ft spacing, or 500-cp wide-beam lights at 12.5-ft spacing. In 1200 ft of visual range at night, a lighting configuration with 500-cp lights, either narrow- or wide-beam, at 25-ft spacing is adequate.

6. Under a daytime condition of 700-ft visual range, a taxiway lighting configuration of 1000-cp lights at 12.5-ft spacing is required for adequate taxiway turnoff identification and guidance. Under the same visual range condition at night, a configuration of 500-cp lights at 12.5-ft spacing is adequate.

7. The wider-beam taxiway lights (see Fig. 5) may offer an advantage over the narrower-beam lights (Fig. 3) by being visible from a point on the runway centerline considerably farther beyond the beginning of the taxiway turnoff.

8. Steady-burning taxiway centerline lights are preferred over flashing lights, at one-flash per second and equal on/off periods, under visibility conditions ranging from clear weather down to 700 ft of visual range.

Recommendations

On the basis of the test results reported herein, it is recommended that:

1. Further studies be conducted on operating runways, using various patterns of colored and white centerline lights to provide runway-distance remaining information.

2. In connection with 1 above, the possibility of increasing the effective intensity of red centerline lights be investigated, through the use of either higher intensity lamps or filters having higher transmission values, or a combination of the two.

3. For category II operations (1200-ft visual range), large-radius turnoffs onto taxiways be marked by steady-burning, green centerline lights spaced 25 ft apart and having intensities of 1000 cp (white) in the daytime and 500 cp (white) at night.

4. For category IIIa operations (700-ft visual range), large-radius turnoffs onto taxiways be marked by steady-burning, green centerline lights spaced 12.5 ft, or less, apart and having intensities of at least 1000 cp (white) in the daytime and 500 cp (white) at night.

5. Further studies be conducted on the possible advantages of marking large-radius taxiway turnoffs in such a way as to provide greater latitude to pilots in identifying a turnoff from points along the runway centerline than would be available under present specifications.

ACKNOWLEDGMENTS

The authors wish to thank the members of the Fog Chamber staff, and in particular R. Ciochon and J. Jeffress, for their valuable assistance in connection with the development and construction of the test equipment and the performance of the tests.

REFERENCES

1. Meehan, F. J., Evaluation of Lighted Crossbars and Lighted Runway Distance Markers, FAA Report No. RD-64-27, February 1964.

2. Gates, R. F., Evaluation of Taxiway Centerline Lighting, FAA Report No. RD-64-46, March 1964.

3. Finch, D. M., R. Horonjeff, and H. G. Paula, Evaluation of Runway Lighting Systems in Dense Fog, FAA Report No. RD-65-58, January 1966.

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APPENDIX A

TEST QUESTIONNAIRE

Information for Pilot Observers

Distance to go information

The Federal Aviation Agency is anxious to obtain your reaction to distance-to-go information. The proposal you will be evaluating consists of adding color to the centerline lights for the last 2000 ft of the runway. The color scheme is as follows:

(a) The last 1000 ft of the runway the centerline lights are red.

(b) From 1000 ft to 2000 ft from the end of the runway the centerline lights will be alternate white and red.

Taxiway Turnoff Evaluation

Centerline lights colored green at various spacing and intensities have been placed in the Fog Chamber. Your task will be to determine the combination of intensity and spacing which you consider adequate for clear weather, 1200 ft and 700 ft visual range. You will actually view two sets of turnoff lights. One set has a relatively narrow horizontal beam spread and the other set has a large horizontal beam spread. The candlepower is the same. The objective is to determine whether a wider beam gives you better guidance. In addition we would like to have you compare the effectiveness of steady burning centerline lights with continuous flashing centerline lights. In dense fog the simulated taxi speeds will be on the order of 15 mph based on the assumption that in this environment turning off the runway on to a taxiway would be done at very low speed. In clear weather the pilot is apt to turnoff at a higher speed consequently simulated taxi speed will be on the order of 50 mph.

UNIVERSITY OF CALIFORNIA

Institute of Transportation and Traffic Engineering

QUESTIONNAIRE

Name:__________________________Affiliation:________________________Date:_____________

A. Distance to go information

1. Could you distinguish between the red centerline and the alternate red-white centerline?

	YES	NO
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

2. Does a colored centerline give you useful information on distance to go?

	YES	NO
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

3. If your answer to any part of question 2 is YES, would you prefer, solid red or alternate red-white for the entire distance?

   Answer: SOLID RED ( ), ALTERNATE RED-WHITE ( ), NO PREFERENCE ( ).

4. Comments (Questions 1 through 3):

Evaluation of high-speed exits (steady burning lights, narrow beam)

5. Do you feel that the taxi lights you saw at 25 feet spacing gave you adequate identification and guidance in:

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

6. If the answer to any part of Question 5 is NO, do you feel that reducing the spacing to 12.5 feet would satisfy your needs in either clear weather, 1200 ft and/or 700 ft of visual range?

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

7. If the answer to any part of question 6 is NO, do you feel that the taxi lights that you saw at 25 ft spacing would give you adequate guidance in:

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

8. If the answer to any part of question 7 is NO do you feel that reducing the spacing to 12.5 ft would give you adequate guidance?

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

9. Comments (Questions 5 through 8)

C. Evaluation of high-speed exits (flashing lights, narrow beam)

10. Do you feel that the flashing lights gave you significantly better identification and guidance than the steady burning lights?

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

11. Comments (Question 10):

D. Evaluation of high-speed exits (steady burning lights, wide beam).

12. Do you feel that the taxi lights you saw at 25 feet spacing gave you adequate identification and guidance in:

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

13. If the answer to any part of Question 12 is NO, do you feel that reducing the spacing to 12.5 feet would satisfy your needs in either clear weather, 1200 ft and/or 700 ft of visual range?

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

14. If the answer to any part of Question 13 is NO, do you feel that the taxi lights that you saw at 25 ft spacing would give you adequate guidance in:

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

15. If the answer to any part of question 14 is NO, do you feel that reducing the spacing to 12.5 ft would give you adequate guidance?

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

16. Comments (Questions 12 through 15, and particularly your views on narrow beam versus wide beam):

E. Evaluation of high-speed exits (flashing lights, wide beam)

17. Do you feel that the flashing lights gave you significantly better identification and guidance than the steady burning lights?

	YES	NO
Clear weather	( )	( )
1200 ft visual range	( )	( )
700 ft visual range	( )	( )

18. Comments (Question 17):

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APPENDIX B

PILOT OBSERVERS' COMMENTS

Runway-Distance Remaining Tests

Questions 1-3 Daytime

"I feel that the best config. would be red and white side by side for last 2000'."

"At 700' hard to see all red for enough, but alternate red-white not as conspicuous as it should be. Maybe 2 reds between each white?"

"The red/white combination is excellent. The red seems to increase the brilliance of the alternate white lights. Don't like solid red."

"With 700 ft Visual Range - the alternate red-white lights are easier to see than the solid red."

"1200 ft Visual Range - can distinguish both solid red and alternate red-white with ease."

"Can see alternate red-white better."

"1. 700 ft visual range YES in a negative sense in that centerline guidance for the most part non-existent with red only."

"2. 700 ft visual range - YES also in a negative way. The solid red segment is seen at such close range that guidance is seriously reduced."

"The alternate Red-White seems to provide a fair amount of distance to go information without seriously deteriorating required guidance cues."

"Red seems to be indistinct as compared to the white in the 700' RVR. Has it been determined that the color red has the maximum contrast to white? Could spacing be varied for the last 1000'?"

"Prefer 2000' red and white and last thousand feet solid red - Possible consideration should be given to making last thousand feet more prominent (reverse sequence of red and red and white is one possibility) than previous 2000'."

"Painted runway markings at far end tell a lot about dist. to do as you go at them! I would like to see them with the centerline reds to full determine whether the red and white combination helps much."

"The arrangement presented using white and red from 3000' to 1500' and pure red from 1500' to zero may provide additional useful information."

"As installed but, the remaining distance to go is very useful information; however, I would like the red lights the last 1000' to be more bright for the lower visual range - if the above is not feasible then I think I would like alternate red-white for the entire distance."

"Prefer as is, with alternate red-white first and then solid red for last 1000'. Wonder whether the colored lights shouldn't extend for the last 3000' instead of only 2000'. Flashing red lights for the final 1500' would be helpful."

"At 700' reds hard to see. Need definite indication of last 1000'. I like the arrangement shown i.e., white to last 2000' then red/white and red for last 1000'. Suggest experiment with Strobes in centerline lights."

"Prefer alternate red and white for about middle third and solid red for last third of runway, or a combination of alternations red and white forming some type of 'caution' zone, and solid red delineating approaching end of runway by some finite distance."

"The colored lights showing distance to go point should be given every consideration including a full scale flight testing at an airport having a lot of traffic to expedite getting data. We need this type of information."

"For the last 1000 to 2000 feet from end of R/W I wonder if lights other than red/white would tell the pilot any more or more quickly. The last 1000 is ok red."

"Red is much too dim. It gets lost in the white lights when RVR is 700 ft. OK on 1200 RVR. With 700 RVR unless you are watching closely the red would be missed."

"Transition between alternating and solid red is a little vague as a visual impression - It seems that a change from the white centerline lights to the red at the warning distance would create more of an impression on the pilot than the runway end is being approached."

"I feel the red centerline lights only would be more practical. You can pick these up immediately and gives you a good warning indicator."

"Increase intensity of red lights so relative intensity would equal white lights."

"Absolutely all red."

"Red lights more difficult to see due to less light transmission. I prefer something on the order of what you have here. There should be a difference in lights so as to ascertain the 2000' mark and the 1000' mark. Possibly combinations of different colors of lights might be tried."

"System is good as is; however, intensity should be increased on red lights. They are difficult to see!"

Questions 1-3 Nighttime

"OK the way it is."

"As is. Here. This is good system, would not change it."

"I like it as is."

"1200 - solid red shows up much better at night than day. Only problem area would be is that pilot may feel he has gone too far, i.e., off runway. The alternate pattern would let the pilot know that the end of the runway is close but he still has 1 or 2,000 ft to go."

"700 ft both patterns showed up very well. I would prefer a combination of the two; say last 1000 ft: red."

Taxiway Exit Tests

Questions 5-8 Daytime

"Narrow beam, higher intensity seems significantly better at 1200' RVR. Narrow beam higher intensity slightly better @ 700 RVR."

"Higher intensity noticeably better in reduced visibility. Need a little more straightaway. Reduced spacing is a little clearer, but not seen sooner, not really necessary."

"Clear - prefer 25 ft spacing with 1000 candlepower.
1200 ft Run #6 was ok; however, looking at #7 with 25 ft spacing (1000 candlepower) was just as good. Gives good curvature of turnoff.
700 ft 25 ft (1000 candlepower) is just adequate; the higher candlepower at 12.5 ft is better."

"Yes, answers for reduced visibility conditions presume the pilot to be properly aligned. This may not always be the case in practice."

"7 marginal."

"Although in question 5 the lights are adequate 12.5 spacing is air improvement. In question 6 @ 700 RVR barely adequate. 25' @ 1000 cp about the same as 12.5' @ 500 cp."

"Reducing the spacing of the lights is a great improvement, however there is some doubt in my opinion at 700 ft Visual Range."

"7 - 700' RVR is marginal - but with $12\frac{1}{2}$' it becomes good."

"12.5 steady burning narrow beam best at 1200' and at 700'. Low intensity adequate under these lighting conditions."

"6 - marginal to N; G; at 1200VR."

"8 - 700 ft RVR is much superior to all conditions above."

"In #9 straight portion was ok but curved portion faded out as turn was followed around."

"Clear wr: #5 the higher candlepower steady light. Demonstration was significantly better. I feel the 25 ft spacing would be adequate."

"6 is barely adequate; however, #8 is best. #8 lites fade in turn in area indicated by arrows."

Questions 5-8 Nighttime

"#5 1200 ft spacing good except that the light could be brighter to give the pilot more decision time to initiate the turnoff."

Question 10 Daytime

"1200' flashing seemed worse. The yellow line seems to be just as significant."

"Not as good as steady; color poor for daylight."

"Flashing lights detract from vision of lights at 1200 & 700' RVR."

"I don't feel that the flashing lights give as much improvement or increasing power as in #7. 1200 & 700 no improvement, harder to identify."

"In clear weather flashing appear to be better; however, they all but disappear at 1200' visual range."

"Flashing lights seriously reduce conspicuity in low visibilities."

"In the 1200' visual range, I missed the first portion of them."

"Consider flashing lights to have little or no value over steady lights under any conditions."

"1200 RVR flashing lites are not as good as the steady, in my opinion. 700' same as 1200 RVR. Believe the off periods detract from conspicuity."

"I do not like the flashing lights especially during reduced visual conditions."

"Flashing lights appear dimmer than steady, and are not nearly so conspicuous. Perhaps this could be overcome by flashing them at such an interval as to be on longer than off."

"Flashing <u>much</u> poorer than steady in <u>all</u> configurations."

"Saw them possibly too late for a 1200 V.R. turn off."

"Flashing narrow beam other than CAVU is no good."

"Very poor."

"Basically, my NO answers are a result of light intensity, not necessarily the flash feature."

"Generally the taxiway light intensity was considerably less than the centerline lights. The flashers are very difficult to see under any configuration. Elimination of the centerline lights in clear weather would make the green lights more obvious. All green light intensity is too low."

"Flashing significantly inferior to steady."

"<u>TERRIBLE!!!</u>"

<u>Question 10 Nighttime</u>

"1200 V.R. - I was disturbed by the halation of the flashing lights. It might be that a higher flashing rate would minimize the effect of going from halation to total darkness. I prefer the steady light.
700 N.G. - Just can't see flashing lights so good as steady."

"Clear - flashing lights could be distracting.
1200', 700' lights are out far too long a period of time."

<u>Questions 12-15 Daytime</u>

"Difference between 25' wide beam at low and high intensity very little @ 1200' RVR."

"No appreciable difference between wide and narrow beam in clear day lgt. In reduced visibility the wide beam is better in guidance when pilot's eye would not be in narrow beam, which will be much of the time. How about high intensity narrow beam or straight portion, and wide beam on turns? Run 15 is best, then 14, then 13. Yellow line is better primary guidance than lights in clear and 1200 ft."

"Prefer narrow beam and don't understand why. Apparent visibility of the green taxi line is better when the cab is moving in reverse."

"<u>700 ft</u> - not much difference in guidance between 25 and 12.5 ft spacing.
<u>Narrow vs Wide beam</u>: could not tell too much difference between the two with clear & 1200 ft wx. At 700 ft, lights were difficult to see."

"Desirable to be able to view lights from wider angle as compared to narrow beam. Note very little intensity increase question 14 & 15 over that in 12 & 13. (Narrow beam showed greater contrast in intensity.) Would prefer brighter lights."

"In the clear weather situation there seemed to be no significant difference. (12) Marginal."

"Wide beam better in clear weather. 12.5 spacing and wide beam is better than either 25 spacing narrow or wide beam."

"Most satisfactory is wide beam, 12.5 spacing and 1000 cp."

"Actually the lighting in the Fog Chamber was adequate, but under actual runway conditions covered with ice or snow, I think a pilot would have a problem with the 700' - the wide beam & $12\frac{1}{2}$' spacing was a big improvement - much easier to start turn."

"Wide beam preferable for 700' RVR."

"#12 prefer the wide beam - much better."

"12. Believe narrow beam gave better definition than wide under same conditions - feel narrow beam superior to wide under all conditions observed. They become visible sooner and 'command' direction better."

"12 - 1200 ft V.R. marginal - especially if pilot is distracted by other cockpit duties or thinking.
13 - Would have been past them before turning.
14 - Would have been past them before turning."

"Wide beam much more distinguishable and better."

"1. Liked wide beam better than narrow in clear weather. Gave better view of entire turnoff.
2. With 1200 RVR liked wide angle better for same reasons.
3. With 700 RVR liked wide angle better for same reasons."

"Clear weather: Higher intensity much more effective. Also felt wide beam provided more runway space to Visual Approach."

"I feel the wide beam gives a better indication than the narrow beam."

"Wide beam easier to see for longer time."

"Wide beam superior although the difference becomes less significant with a decrease in RVR."

"#14 adequate except narrow much easier to see."

Questions 12-15 Nighttime

"Wide beam lights are much better."

"12 - OK for 1200 VR."

"Wide angle lights much superior to narrow."

"Clear - narrow vs wide - couldn't tell very much difference but believe wide beam is a little better.
1200 & 700' - Wide beam gives a 'hollow' effect; however, with the closer spacing it gives a pretty good lead on for turnoff. In general - prefer narrow beam over the wide beam at 1200 & 700 ft visual range."

Question 17 Daytime

"1200 ft flashing worse than steady."

"Flashing worse than steady in all areas."

"Impressions after 1200' RVR tests before 700' RVR -
a. Don't see any advantage to flashing lights.
b. Don't see any advantage to wide beam lights."

"I believe the flashing lights are a hindrance in identification. This is especially true at the lower visual range. The lights are not 'on' long enough to give a good line to follow."

"Flashing lights seriously reduce conspicuity in low visibilities."

"Not as effective as the steady lites."

"Might be better if flash-interval as suggested in my comment to #11.
Comment to #11: 'Flashing lights appear dimmer than steady, and are not nearly so conspicuous. Perhaps this could be overcome by flashing them at such an interval as to be on longer than off.'"

"Prefer wide beam - believe it much better; also prefer flashing lights - they draw the pilot's attention and more readily distinguishable."

"It seems odd that the flashing wide beams appear superior to steady wide; while the steady narrow appear superior to both the flashing narrow and steady wide. Believe the steady narrow are best (all the above relates to clear condition). Flashing lights poorest of all - overall brilliance - poor."

"Clear weather: Wide beam - lights much better, also flashing feature is desirable and gives the pilot a clearer message that a turnoff is for him. Most A/P have so many different type and color lights that an unfamiliar pilot is confused as to ground control instructions and I believe that the flashing fixtures feature is very desirable.

"1200 & 700 RVR: Wide beam steady lights much better at reduced visibility or any conditions other than - CAVU - flashing light condition - I had a tendency to lose lights between flashes."

"Just as bad as narrow."

"The flashing lights in clear weather do not give too much additional indication."

"Clear weather - prefer wide angle lights."

"TERRIBLE!!!"

Question 17 Nighttime

"Wide beam flashing much better than narrow beam.
700 RVR - Too much halation with flashing light - hard to follow."

"Can't see so clearly with flashing lights due to halation effect and darkness after flash."

"Clear - narrow vs wide - couldn't tell very much difference but believe wide beam is a little better."

APPENDIX C
OBSERVER ROSTER

The following pilots participated as observers in the tests described in this report.

Name	Affiliation
Anderson, J. A.	United Air Lines
Armstrong, Don	FAA WE-160
Banning, E. R.	Air Line Pilots' Association - Pan American Airways
Bassett, C. E.	Air Line Pilots' Association - Pan American Airways
Cooper, R. W.	Pan American Airways
DeCelles, J. L.	Air Line Pilots' Association - Pan American Airways
Egbert, F. M.	United Air Lines
Fitzgerald, D. W.	United Air Lines
Fleming, J. L.	Pan American Airways
Francer, John	FAA WE-160
Glazier, F.	Air Line Pilots' Association - Trans World Airlines
Hagins, J. C.	Air Line Pilots' Association - Trans World Airlines
Halperin, David	Air Line Pilots' Association - Trans World Airlines
Henon, R. G.	United Air Lines
Hughart, D. W.	United Air Lines
Kettering, C. W.	United Air Lines
Linnert, Ted	Air Line Pilots' Association
Loewe, W. R.	United Air Lines
Madson, E. W.	United Air Lines
Minor, J.	Air Line Pilots' Association - Pan American Airways
Peterson, Roy E.	FAA - LAX
Price, W. J.	United Air Lines
Tatman, H. E.	United Air Lines
Tritt, E. F.	United Air Lines
Tymczyszyn, Jos. J.	FAA WE-160